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Comment on: "Meson Masses in Nuclear Matter"

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In a recent letter [1], Eletsky and Ioffe estimated the energy shift of ρ-meson with *high* momentum ($\mathbf{q}$) in nuclei using the Glauber approximation. They also made remarks on the *low* $\mathbf{q}$ vector mesons in medium. In this Comment, we will discuss the second point and show that (i) mean-field physics for the mass shift of low-$\mathbf{q}$ mesons is overlooked in [1], and (ii) the *short distant* operator product expansion (OPE) is relevant to analyze the low-$\mathbf{q}$ mesons in QCD sum rules contrary to the claim in [1].

Mesons in nuclei have considerable multiple scattering when $|\mathbf{q}|^{-1} \gg d$ (d is the inter-nucleon distance). The relevant quantity here is known to be a polarization function (generalized optical potential) $\Pi(\omega, \mathbf{q})$ [2], which is written, up to the Lorentz-Lorenz correction, as

$$\Pi(\omega, \mathbf{q}) = -16\pi \int \frac{d^3\mathbf{p}}{(2\pi)^3} F(\omega, \mathbf{q}; \mathbf{p}) n_{_F}(\mathbf{p}), \tag{1}$$

where $n_{_F}$ is the fermi distribution, F is an *in-medium* forward scattering amplitude of an incoming vector-meson (V) with a nucleon (N) of momentum $\mathbf{p}$. At extremely low density, eq.(1) reduces to $\Pi(\omega, \mathbf{q}) = -4\pi F(\omega, \mathbf{q}; 0)\rho$, which does not however have practical use, since F has not only a smooth $\mathbf{p}$-dependence (from e.g. the t-channel meson exchanges considered in [3]) but also a possible rapid $\mathbf{p}$-dependence from s-channel baryon-resonances coupled to the V-N system. In other words, the averaging of F over the fermi sea is essential for the mass shift at low $\mathbf{q}$. Note also that low-$\mathbf{q}$ mesons probe large distances and hence the averaged nuclear properties. The mean-field (MF) + RPA treatment of Π, which has been employed in hadronic model calculations (see e.g. [4]), is most suited for studying these features. The importance of this MF description for low-$\mathbf{q}$ mesons is overlooked in [1].

The MF description is also compatible with the finite-density QCD sum rules [5]. Consider the vector-current correlation in medium,

$$D_{\mu\nu}(Q^2, Q^2/q \cdot P) = i \int d^4x e^{iqx} \langle P|T[J_\mu(x) J_\nu(0)]|P\rangle \ , \tag{2}$$

with $Q^2 \equiv -q^2$ and $|P\rangle$ being the nuclear ground state with momentum P^μ. At large Q^2, one can make OPE in two ways [6]: the short-distance (SD) expansion where $(Q^2, Q^2/(q \cdot P)^2) \rightarrow$

(∞, finite), and the light-cone (LC) expansion where $(Q^2, Q^2/q \cdot P) \to (\infty, \text{finite})$. Both are at best an asymptotic expansion in $1/Q^2$ with different composite operators contributing at each order: The SD (LC) expansion is dictated by the dimension (twist) of the operators. Since we are interested in $\mathbf{q} \simeq 0$ with $\mathbf{P} = 0$, OPE in the deep-euclidian region $(-\omega^2 \to \infty)$ is obtained from the SD expansion by re-expanding $1/Q^2$ and $(q \cdot P)^2/Q^2$ in terms of $1/\omega^2$, which is a natural generalization of the QCD sum rules in the vacuum [5,8]. More importantly, from the analytic properties of $D_{\mu\nu}$, one can relate the OPE to the spectral density via the well-known fixed $\mathbf{q}$ dispersion relation [7]

$$\text{Re } D(\omega^2 < 0, \mathbf{q}) = \int_0^\infty dx^2 \frac{\rho(x, \mathbf{q})}{(x^2 - \omega^2)} + (\text{subtraction}). \tag{3}$$

As in the vacuum sum rules, we keep only the contributions up to dimension 6 operators. The actual expansion parameter at low density is $\Lambda_{QCD}^l p_F^m |\mathbf{q}|^n / \omega^{l+n+m}$ (p_F is the fermi momentum). Density dependent contributions from dimension 4 and dimension 6 operators have been shown not to spoil the asymptotic nature of the series [5]. In the work by Drukarev and Levin [9], a kinematics $Q^2 \to \infty$ with $s = (q + P/A)^2$ fixed (A is the number of nucleons) or its variant are adopted. This leads to the LC expansion as quoted in [1]. However, a dispersion relation for Q^2 with fixed s is *assumed* in [9]. Such a dispersion relation, unlike eq.(3), cannot be derived from analytic properties of $D_{\mu\nu}$ alone [8]. Also fixing s inevitably gives a large $\mathbf{q}$ limit, which is inappropriate to extract the MF physics we are interested in.

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